AIR POLLUTION STUDY OF A LOCOYARD

By

R. S. UJLAYAN

DEPARTMENT OF CIVIL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY KANPUR

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AIR POLLUTION STUDY OF A LOCOYARD

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In Partial Fulfilment of the Requirements
for the Degree of
MASTER OF TECHNOLOGY

By
R. S. UJLAYAN

to the

DEPARTMENT OF CIVIL ENGINEERING
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CE-1977-M-UJL-AIR.

CERTIFICATE

Certified that the work presented in this thesis entitled "Air Pollution Study Of A Locoyard" by Shri R.S. Ujlayan has been carried out under my supervision and it has not been submitted elsewhere for a degree.

D.K. GHOSH
Lecturer
Environmental Engineering Division
Department of Civil Engineering
Indian Institute of Technology, Kanpur

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ABSTRACT

The objective of this study was to find out approximate emission factors for steam locomotives and to assess the ambient air quality prevailing in the locoyard. Sulphur dioxide and particulate matter were taken as the parameters for emission factors and ambient air quality.

Emission factors based on the rate of coal consumption have been reported for four different type of steam locomotives. It was observed that there is slight variation in emission factors in stationary and moving positions of the steam locomotives. Emission

factors observed for different types of steam locomotives showed appreciable variations.

Sulphur dioxide and particulate matter concentrations prevailing in the ambient air were found to be quite high. A high percentage of particulate matter was found to be in the size range of less than and equal to 10 micron, and their distribution was found to be log normal.

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1. INTRODUCTION

The ambient air quality depends on both natural and manmade emissions. The amount of air pollutants released as well as the proximity of air pollutant contributors in areas which have poor dilution capabilities due to meteorological conditions will result in very poor ambient air quality. Such poor quality air, in addition to affecting health, can damage vegetation, affect inanimate objects, and reduce visibility. All of this can occur at extremely low pollutant concentrations.

It seems, most air pollution arise from the emission of the products of combustion. In fact the air pollutants resulting from combustion of fuels using the stored chemical energy of the fuel to produce heat and work, are the major contributory factors to air pollution in urban communities.

There are various sources spewing out various types of air pollutants into the atmosphere. Out of all the sources, transportation systems alone are responsible for sixty percent of all the air pollution in world today (Ross, 1972).

Out of all the transportation modes, railway is one of the major ones. Specially in context with India, where private vehicles are less, railway is most important mode of transport. India is having a second longest railway network in the world. The area covered by Indian railway is about 3,260,000 square kilometres. Everyday about 6,400 passenger trains and 4,400 goods trains are running on different tracks (Rangwala, 1971).

Such a large number of trains running on various routes, with steam or diesel engines, are bound to contribute a considerable amount of air pollutants. Almost every train passes through the agricultural fields and the pollutants emitted in the air over these fields may cause considerable damage to the crop. In U.S. alone yearly total cost of air pollution on vegetation is close to a billion dollars (Stern et al. , 1968).

For maintenance and refuelling, the engines are regularly received in locoyards. Locoyards, with so many engines, standing, arriving, and departing provide a problem of local air pollution.

Northern Railway locoyard of Kanpur, with about 1,700 workers working round the clock in three shifts for maintenance of about sixty steam engines a day, is likely

to deteriorate the local ambient air quality which in turn may adversely affect the health of loco workers.

The study reported herein was undertaken to study the emission of sulphur dioxide and particulate matter from steam locomotive as well as to ascertain the concentratio of these pollutants in the ambient air of the locoyard.

1.1 SPECIFIC OBJECTIVES OF THE STUDY:

The above mentioned study was undertaken with the following objectives:

(1) Quantifying the amount of sulphur dioxide and particulate matter emitted by the steam locomotives under stationary and moving conditions, and to find the emission factors for these pollutants.

(2) Study of sulphur dioxide and particulate matter concentrations present in the ambient air of locoyard.

(3) Interpreting the size distribution of particulate matter present in the ambient air which may indicate the potential of adverse health effects.

2 LITERATURE REVIEW

2.1 LOCOMOTIVE BOILER

Locomotive boiler is an internally fired horizontal multi-tubular portable firetube boiler specially designed to cope up with sudden variations in demand of steam even at the cost of efficiency, though efficiency is quite high at rated output. It is a highly refined unit, not to be confused with relatively simple locomotive type boiler. Pressure range is upto about 21 Kg./Cm^2. Steaming rates are as high as 55 to 70 Kg. per square metre of the heating surface per hour. The boiler for locomotive is having a steam dome, which, if removable serves as man-hole. Some boilers have in-tube super-heater.

Locomotive boilers manufactured at Chittaranjan Locomotive Works produce 18,700 lb./hour steams at 210 lb./in^2 gauge (14.764 Kg./Cm.^{2} gauge) and superheated to 700°F, at the rate of 3,500 lb. coal/hour (Ballaney, 1973).

2.2 COALS USED BY INDIAN RAILWAYS

The quality of coal is directly related to the generation of steam and emission of pollutants by a locomotive. The coal specifications usually include ash content, moisture

content, calorific value, impurities like sulphur, size, grindability, volatile matter, and fusibility of ash.

High percentage of ash results in increased fuel consumption and particulate emissions. Moisture content is important from the burning point of view. According to a report published by Central Board of Irrigation and Power (1972) there is approximately 0.1 percent loss in efficiency of boiler with every one percent increase in moisture content. Calorific value dictates the fuel requirements of the boiler. It directly affects the operating cost and efficiency of the locomotive boiler. Impurities present in coal are responsible for emission of various pollutants, e.g. sulphur present in coal is responsible for emission of oxides of sulphur as pollutants. Size is important for ease of handling. For various handling equipments the size requirements are different. Grindability is important when coal is to be pulverised before feeding. Heat produced by volatile matter is quickly available which is useful for taking care of sudden increases of load. The proportion of total heat value contributed by the volatile matter in bituminous coals generally varies from 25 to 40 percent. The ash fusion temperature (Published report of Central Board of Irrigation and Power, 1972) determines the

suitability of coals for dry bottom or wet bottom furnaces. A fusion temperature of above 1,350°C and below 1,200°C is suitable for dry and wet bottom furnaces respectively.

2.2.1 Properties Of Coals Supplied To Indian Railways :

Based upon the calorific value and ash and moisture content, the Indian Railways specify the coals as given in tables 1 and 2.

TABLE 1

NON COKING COALS (HIGHLY VOLATILE AND HIGH MOISTURE)

Grade of coal	% Ash and moisture*	% Sulphur (Total)	Calorific value in BTU/lb.	
			Range	Average
Selected A	Upto 17.5	$<$ 1	12,200-11,800	12,000
Selected B	17.5 to 19.0	$<$ 1	11,800-11,600	11,700
Grade I	19.0 to 24.0	$<$ 1	11,600-10,800	11,200
Grade II	24.0 to 28.0	$<$ 1	10,800-10,000	10,400

* Moisture 4 to 5 percent.

TABLE 2

COKING COALS (LOW VOLATILE AND LOW MOISTURE)

Grade of Coal	% Ash and Moisture*	% Sulphur (Total)	Average Calorific Value in BTU/lb.
A	Upto 13	< 1	12,850
B	13 to 14	< 1	12,850
C	14 to 15	< 1	12,850
D	15 to 16	< 1	12,500
E	16 to 17	< 1	12,500
F	17 to 18	< 1	11,950
G	18 to 19	< 1	11,950
H	19 to 20	< 1	11,200
HH	20 to 24	< 1	11,200

* Moisture 1 to 3 percent.

2.3 COAL COMBUSTION

Combustion is a chemical process in which coal and oxygen are made to react at a temperature above the kindling temperature. For complete combustion it is necessary that there is a good contact between coal and the air. The gaseous products of complete combustion are water, carbon dioxide, sulphur dioxide, and various metal oxides. Common products of incomplete combustion are carbon (soot), carbon monoxide, hydrocarbons of various types, and hydrogen chloride. The solid products of combustion include ash and clinker. Table 3 adopted from Ledbetter (1972) lists the various gaseous and particulate emissions from coal burning.

The emission rate of particulate matter from coal fired furnaces is related to many factors like gas velocity, particle density, particle size, fuel burning rate, combustion efficiency, flue gas temperature, furnace configuration, coal consumption, and the initial state of raw coal. According to Faith (1959) the following variables are thought to be the most important in relation to particulate emission :

(i) Amount of ash in the coal;

(ii) Method of burning the coal; and

TABLE 3

EMISSIONS FROM COAL COMBUSTION

ombustion nit	Particulate			Gaseous ($lb/10^6 Btu$)				
	Amount ($lb/10^6$ Btu)	Size M_g	Size σ_g	Nitrogen Oxides	Aldehydes (formaldehyde)	Carbon-Monoxide	Hydro-Carbons	Sulphur Dioxide
ulverised[a]	8	20	3.6	0.8	2×10^{-4}	0.015	0.008	1.6S
yclone	1	4	3.0	2.4	1.7×10^{-4}	Trace	Trace	1.6S
preader poker	6.5	70	4.7	0.7	0.6×10^{-4}	0.03	0.009	1.6S
and-fired	1	–	–	0.3	2×10^{-4}	2.00	0.4	1.6S

General, dry bottom, and wet bottom without fly-ash reinjection. Fly-ash reinjection increases the particulate load to about 12 $lb/10^6$ Btu.

= percent weight of sulphur

(iii) Rate at which the coal is burned.

Coal ash content is the governing factor in fly-ash emission. Higher the ash content higher the fly-ash emission.

The method of burning the coal influences particulate emission rates. When coal is thrown or blown into a furnace, combustion takes place in suspension. As the pieces of coal burn, they get smaller and thus their chance of being exhausted with stack gases is increased. When coal is pushed or pulled into a furnace to form a bed, the coal or ash has less chance of being entrained by the flue gases because of impingement on to large particles. When coal is introduced tangentially into a cylinder, such as the cyclone furnace, the former acts as a cyclone separator and thus reduces emission.

Velocity of gases is proportional to the firing rate of a furnace. As the velocity of gases passing through furnace increases, larger particles of coal and ash are carried out of the furnace.

Emission of gaseous pollutants depend mainly on the chemical constituents of the coal. Other factor responsible for gaseous emission is the degree of combustion. Under different states of combustion different pollutants will be

emitted in various quantities.

Main pollutants emitted by locomotive are oxides of sulphur and nitrogens, particulate matter, hydrocarbon vapours, and carbon monoxide (Hal *et al.*, 1976).

2.4 EMISSION FACTORS

Perkins (1974) defines emission factors as the values of various emissions by weight compared to some given basis. This basis may be the rate of fuel consumed, size of equipment, output of the product, or any other suitable basis. In case of coal burning usually emission factor is given as amount of emissions per tonne of coal burned or amount of emissions per BTU of energy produced.

Tables 4 and 5 adopted from Perkins(1974) gives expected gaseous and particulate emission factors for different type of units, using coal as fuel.

TABLE 4

GASEOUS EMISSION FACTORS FOR COAL COMBUSTION (LB./TON OF COAL)

Pollutants	Type of Unit		
	Power Plant	Industrial	Domestic and Commercial
Aldehydes (HCHO)	0.005	0.005	0.005
Carbon monoxide	0.5	3	50
Hydrocarbons (CH_4)	0.2	1	10
Oxides of Nitrogen (NO_2)	20	20	8
Oxides of Sulphur (SO_2)	38 S	38 S	38 S

S = % Sulphur in Coal

TABLE 5

PARTICULATE EMISSION FACTORS FOR COAL COMBUSTION WITHOUT CONTROL EQUIPMENT

Type of Unit	Particulate per ton of coal burned*, lb.	Percent 44 Microns or greater	Percent 20 to 44 microns	Percent 10 to 20 microns	Percent 5 to 10 microns	Percent less than 5 microns
Pulverized						
General	16A	25	23	20	17	15
Dry bottom	17A	25	23	20	17	15
Wet bottom without fly ash reinjection	13A	25	23	20	17	15
Wet bottom with fly ash reinjection+	24A	25	23	20	17	15
Cyclone	2A	10	7	8	10	65
Spreader stoker:						
without fly ash reinjection	13A	61	18	11	6	4
with fly ash reinjection+	20A	61	18	11	66	4
All other stokers	5A	70	16	8	4	2
Hand-fired equipment	20	-	-	-	-	100

* The letter A on all units other than hand-fired equipment indicates that the percent ash in the coal should be multiplied by the value given.

+ Values should not be used as emission factors. Values represent the loading reaching the control equipment always used on this type of furnace.

2.5 TRANSPORT OF AIR POLLUTANTS

Transport of air pollutants is a part of self-purification cycle of atmosphere. Movement of pollutants in the atmosphere is helped by several physical, chemical, and meteorological factors. Based upon the size of the pollutants they settle down, which in turn are taken care of by soil, vegetation, and water bodies. Based upon the chemical properties there are photochemical reactions in the atmosphere. Meteorological conditions such as wind speed, wind direction, stability of the atmosphere, gustiness, turbulence, and rain play a major role in the movement of pollutants.

Many theories have been proposed to predict the transport of pollutants in downwind direction. Most widely used theories for dispersion are those developed by Pearson and Bosanquet and by Sutton. Both the theories predict concentrations of pollutants along the wind direction. The main parameters used in these theories are meteorological conditions, source and emission characteristics, and topography of the region.

The meteorological parameters which affect the pollutant transport are :

(i) Wind speed and direction for advective transport,

(ii) Atmospheric turbulence or stability for dispersion or eddy diffusion : which in turn depends on

(a) insolation,

(b) lapse rate,

(c) wind velocity profile, etc.

(iii) Precipitation : This may cause wetting and dissolution of pollutants and a washout of the atmosphere.

Source and emission characteristics which affect the pollutant transport are :

(i) Effective height of the stack,

(ii) Velocity of emission,

(iii) Temperature of emission, etc.

Topography of the region is important because the wind profile depends on topographical features. Height of the buildings, valley, hills, and roughness of the surface are the main factors to be considered.

Apart from these general parameters, there are other parameters which may play important role under particular conditions. To cite a few :

Samson et al.(1975) concluded that high particulate concentrations correlate well with wind flow, regardless of relative location of receptor to local sources. They reported that ambient background concentrations inherent in different masses more consistently affect suspended particulate levels than the diffusion from local sources.

Derham et al.(1974) concluded that there is a direct relationship between the inside and outside concentrations, and that the phase lag between the concentrations depends principally on the ratio of the building volume to the ventilation rate.

Thompson et al. (1973) concluded that particulate matter levels indoors depend largely upon velocity of air movement. Indoor areas, with light foot traffic and low ventilation rates have reduced amounts of particulate.

2.6 THE EFFECTS OF AIR POLLUTION

The history of man's concern about the effects of polluted air on his health and comfort is long. The modern intense concern is due largely to a series of episodes of fumigation in urban air with associated increase in mortality; the most effective of these as a stimulus to

research and legislation, was the 'London Smog' of December, 1952.

The problem of air pollution is indeed complex. New sources of pollutions have been responsible for new problems and heightened anxiety, until today there can be few aspects of public health which are the subject of so much intensive research and debate. Today there remains no doubt about air pollution being adversely affecting human health, vegetation and animal injury, causing damage to property, and affecting meteorological conditions.

2.6.1 Adverse Effects On Human Health :

Respiratory tract is the principal site of air pollution attack on the human body. Air enters through the nose which, if in healthy condition, filters particulate matter larger than 10 micron diameter. Particulate matter 2-10 micron diameter, settles or impinges upon the walls of the trachea, bronchi, and bronchioles; these foreign particles are escalated by ciliary action to the mouth and swallowed. Particles approximating 0.1-2 micron may reach the alveoli. The gases, specially the sulphur oxides, nitrogen dioxide, and the oxidants, are differently absorbed by the walls of the respiratory tract. Sulphur dioxide may

reach the alveoli when the gas is either sorbed on small particulate matter or oxidized to a sulphuric acid aerosol of proper size. When the upper tract is affected, the outcome is coughing, sneezing, thickening and secretion of mucus, and narrowing or complete closure of the glottis (opening of the larynx) (Zutshi, 1970).

a) Pollutant Combinations : Suspended particles may modify the response to simultaneously inhaled gases. An excessive exposure to sulphur dioxide in the presence of particulates induces chronic bronchitis and emphysema. Evidence has accumulated that a 24-hour exposure to about 0.2 ppm of sulphur dioxide with particulates is a recognizable health hazard (Zutshi, 1970). The combination of gases with particles has been shown to cause changes in toxicity to rodents (LaBelle et al., 1955). Such potentiation or synergism may arise in several ways. For example, a water soluble gas might be carried by adsorption on penetrating particles of small size past the region of scrubbing action in the upper tract and into the deeper lungs. Another mechanism might be the increased local tissue dose at the point of particle contact resulting from the concentration of gas around the particle. Biological interaction may

be another mechanism of synergism, which could conceivably arise from the induction of bronchoconstriction by non-toxic aerosols (Dautrebande _et al._, 1958) in the presence of simultaneously inhaled irritant gases.

b) Studies Relating Health And Air Pollution : Manos and Fisher (1959) indicated that four causes of death produce a large number of high positive correlation with the various indexes of air pollution. These are :

1. Malignant neoplasm of esophagus and stomach.
2. Malignant neoplasm of the trachea, bronchus and lung.
3. Arteriocleroti c heart disease, including coronary disease.
4. Chronic endocarditis not specific as rheumatic, and other mycardial degeneration.

Prindle (1959) concluded that the mechanism of experimental epidemiology, toxicology, and physiology with study of whole community populations for their patterns of mortality and morbidity, will have to be undertaken before achieving clarification of the relationship between air pollution and disease.

Ghosh (1971) has established a correlation between long term low level air pollution and the incidence of some respiratory diseases. Garud (1971) established a strong correlation between the growth impairment of children and sum of the concentrations of sulphur dioxide and total oxidants. Schimmel and Greenburg (1972) reported that there are excess number of deaths due to air pollution. Cough, chest discomfort, and restricted activity are most consistently affected during episodes (Nelson et al., 1973).

Goldstein and Block (1974) observed no relationship between daily visits to emergency rooms and daily levels of either smokeshade or sulphur dioxide in Harlem whereas in Brooklyn a relatively strong correlation between daily visits for asthama and daily levels for sulphur dioxide, but not with smokeshade had been observed over and above the effect of temperature. In both areas there was a strong relationship between daily visits for asthma and the first cold spell of the full season.

2.6.2 Other Effects :

a) Vegetation : Effect on vegetation usually occurs through leaf damage because leaf gives easy access to pollutants. Table 6 adopted from Perkins (1974)lists the effects of some pollutants on plants.

TABLE 6

EFFECTS OF POLLUTANTS ON PLANTS

Pollutant	Dose	Effect	Specific Cases
Ozone	Mild	Flecks on upper surface, premature aging, suppressed growth.	0.06 ppm for 3-4 hours damages alfalfa, white pine.
	Severe	Collapse of leaf, nercosis and bleaching.	
PAN	Mild	Bronzing of lower leaf surface (upper surface normal), suppressed growth: young leaves more susceptible.	0.03 ppm accute damage to sensitive plants: spinach; romaine lettuce, certain flowers.
SO_2	Mild	Interveinal chlorotic bleaching of leaves.	1 ppm for fumigation times causes damage to alfalfa, cotton, barley, 0.3 to 0.5 ppm for several days on sensitive plants causes chronic injury.
	Severe	Nercosis in interveinal areas and skeletonized leaves.	
NO_2	Mild	Suppressed growth; leaf bleaching.	0.5 ppm for 10-12 days suppressed growth on pinto beans and tomatoes. Navel orange yield greatly reduced at 0.25 ppm for 240 days, 0.5-1 ppm for 35 days.

b) Soiling : Soiling is due to settleable portion of the suspended particulate matter. Soiling usually affects the economy and not the physical or health damage. Due to soiling there are increased costs of house cleaning, cleaning and maintenance of clothes, frequent washing and distempering of walls, and maintenance of the roof top of buildings.

c) Visibility : Decreased visibility obviously interferes with certain human activities, such as safe operation of air craft and automobiles and the enjoyment of scenic vistas. Visibility reduction related to air pollution is caused primarily by the 0.1 micron to 1.0 micron radius particles in the atmosphere. Deterioration of visibility caused by suspended particulate matter is the result of absorption and scattering of light. Both the brightness of the viewed object and its visual contrast with the background are reduced by attenuation of light due to scattering and absorption. In addition, a further contrast reduction results from scattering of sunlight into the observer's line of sight. Loss of brightness and contrast are responsible for the subjective impression of impaired visibility.

2.6.3 Air Quality Standards :

Air quality standards prescribe pollutant levels that cannot legally be exceeded during a specific time in a specific geographical area. Air quality standards are based upon air quality criteria, with added factors of safety as desired.

No standards have yet been developed for Indian conditions. Table 7 adopted from Perkins (1974) and table 8 adopted from Arceivala et al. are given to serve as a guideline for ambient air quality and work room air quality.

2.7 PARTICULATE MATTER CHARACTERISATION

a) Particle Size : Information on particle size distribution in the gas stream and ambient air is important from two points : (1) for proper selection of gas cleaning equipment and (2) for its potential as health hazard. Particle size in general cannot be specified uniquely by a single parameter. For irregular dust particles, the average dimensions along three mutually perpendicular axes may be used, or the diameter of a sphere having the same volume or the same surface area as the particle may be chosen. Obviously, the more irregular the shape of the particles

TABLE 7

AMBIENT AIR-QUALITY STANDARDS

Pollutant	Averaging time	California Standards		Federal standards		
		Concentration	Method	Primary	Secondary	Method
Sulphur Dioxide	Annual average	–	Conductimetric method	80 $\mu g/m^3$ (0.03 ppm)	60 $\mu g/m^3$ (0.02 ppm)	Pararosaniline Method
	24 hr	0.04ppm (105 $\mu g/m^3$)		365 $\mu g/m^3$ (0.14 ppm)	260 $\mu g/m^3$ (0.10ppm)	
	3 hr	–		–	1300 $\mu g/m^3$ (0.5 ppm)	
	1 hr	0.5 ppm (1310 $\mu g/m^3$)		–	–	
Nitrogen dioxide	Annual average	–	Saltzman method	100 $\mu g/m^3$ (0.05ppm)	Same as primary standard	Colorimetric method using NaOH
	1 hr	0.25 ppm (470 $\mu g/m^3$)		–		
Suspended particulate matter	Annual Geometric-mean	60 $\mu g/m^3$	High volume sampling	75 $\mu g/m^3$	60 $\mu g/m^3$	High volume sampling
	24 hr	100 $\mu g/m^3$		260 $\mu g/m^3$	150 $\mu g/m^3$	
Photochemical oxidants (corrected for NO_2)	1 hr	0.10 ppm (200 $\mu g/m^3$)	Neutral buffered KI	160 $\mu g/m^3$ (0.08ppm)	Same as primary standard	Chemiluminiscent method

TABLE 8

AMBIENT AIR QUALITY STANDARDS OF WORK ROOM

AIR THRESHOLD LIMIT VALUES (TLV) FOR SOME POLLUTANTS

Country or State	Ambient Air		Workroom TLV (8 hr per day for 5 days) ppm
	Average Concentration ppm	Time hrs.	
i) <u>Sulphur Dioxide</u>			
California (Adverse level)	0.3	8.0	5.0
California (Serious Level)	5.0 5.0	1.0	
California (Emergency level)	10.0	1.0	
U.S.S.R. (Max. 0.18)	0.05	24.0	4.1
West Germany (Max. 0.3)	0.20	0.5	5.0
ii) <u>Carbon Monoxide</u>			
California (Serious level)	30.0	8.0	100.0
California (Serious level)	120.0	1.0	
U.S.S.R. (Max. 4.8)	0.8	24.0	18.0
iii) <u>Hydrogen Sulphide</u>			
California (Adverse level)	0.1	1.0	20.0
U.S.S.R. (Max. 0.005)	0.005	24.0	6.7
West Germany (Max. 0.2	0.1	0.5	20.0

NOTE: For air-borne dust (< 10 micron) workroom TLV as specified by International Labour Organization=$1 mg/m^3$

the greater will be the variations in equivalent diameters. For extremely irregular particles of shapes like plates, rods, or stars, some other measure, such as specific surface or settling rate, will usually be more significant. Determination of particle size cannot be unique except for the special case of spherical particles. For all other cases,the results will depend on the experimental method used. Table 9 adopted from Stern et al.(1973) lists the methods of measurement for various size ranges of particles.

b) Particle Shape : As noted above, particle size analysis does not account for the multiplicity of particle shapes, which are of many types, from simple spheres to complex stars and chain-like aggregates. Fogs, mists, and some smokes are composed of spherical liquid or tarry droplets. Many flyash particles, produced in the combusion of pulverized coal, are hollow spheres or cenospheres, frequently with much smaller satellite particles attached to their surfaces. Dust particles usually are irregular in shape. Many metallurgical fumes have a star-like or plate-like shape; others are needle-like and tend to form agglomerated chains. Particle shape and surface condition influence handling characteristics, chemical reactivity,

TABLE 9

PARTICLE SIZE RANGES AND THEIR METHODS OF MEASUREMENT

Micron	Ions	Nuclei	Visibility	Suspended or settleable non air borne	Dispersion aerosol	Condensation aerosol	Pollen or spores	Diffusion or settling
10^{-4}–10^{-3}	Small	–	–	Suspended	–	Gas molecules	–	Diffussion
10^{-3}–10^{-2}	Intermediate and large.	Aitken nuclei	Electron microscope	Suspended	–	Vapor molecules	–	Diffussion
10^{-2}–10^{-1}	Large	Aitken and condensation	Electron microscope	Suspended	–	Fume-mist	–	Diffusion
10^{-1}–10^{0}	–	Condensation nuclei	Microscope: electron and optical	Suspended	Dust-mist	Fume-mist	–	Diffussion and sedimentation
10^{0}–10^{1}	–	–	Microscope: optical	Suspended and settleable	Dust-mist	Fume-mist	–	Sedimentation
10^{1}–10^{2}	–	–	Eye sieves	Settleable	Dust-mist	Mist-Fog	Pollen and spores	
10^{2}–10^{3}	–	–	Eye sieves	Nonairborne	Dust-spray	Drizzle-Rain	–	Sedimentation
10^{3}–10^{4}	–	–	Eye sieves	Nonairborne	Sand-rocks	Rain	–	Sedimentation

adsorption potential, and flammability limits among other particulate properties.

c) General Techniques of Characterization : Gilmore and Hanna (1975) while testing the applicability of the mass concentration standards for particulate matter in Alaskan areas reported that a particulate matter ambient air standard based on mass concentration alone is unjustified unless data can be provided for each sampling location which relates the measurement to a standard distribution of particle size upon which standards have been based.

Whitby et.al. (1974) while discussing Lee (1972) expressed that it is useful to consistantly plot aerosol size distribution data (such as number, area, volume, and mass) on several different sets of coordinates. These different graphing approaches are necessary to provide insight into the relevant integral properties of the system, such as total volume, surface area, and light scattering. Replying their discussion, Lee (1974) reported that expressing a particle size distribution as a log normal function (plotting the logarithm of the size as a function of the cumulative percentage mass $\leq$ the stated size on a probability scale) has been the most widely used and

generally accepted method of treating aerosol data since 1930's. The major advantage of a log normal plot is that the size distribution can be directly correlated with lung deposition based on the mass aerodynamic equivalent diameters. The log normal size curves can be used to assess the aerosol fraction which can penetrate and be retained in various portions of the respiratory systems.

Nader (1975) considers that there are three distinct particle parameters with which the size distribution can be associated, namely number (N), surface (S), and mass concentration (M). Willeke and Whitby (1975) feel that for size distribution interpretation of atmospheric aerosols, most important parameters are surface, volume, number and mass. Whitby et al. (1972) while studying the aerosol size distribution of Los Angles smog reported that in addition to the usual log $\Delta N/\Delta D_p$ versus log D_p plot (D_p is the particle diameter), it was found that a plot of $\Delta V/\Delta \log D_p$ versus log D_p (V is the particle volume) was very useful for characterizing the distribution of particles larger than 0.05 micron. From the volume distribution plot, it was found that the smog aerosol was universally bimodal with the saddle point in the 1 to 2 micron size range and

with the volume fraction for the individual size distributions below 1 micron being characterized with a grand correlation coefficient of 0.9719 with log normal distributions. For sizes above 1 micron, the volume distribution increases steadily upto 6.8 micron.

Mainwaring and Harsha (1976) while studying the size distribution of aerosols in Melbourne city air used the log probability plot and mass distribution versus size plots for interpretation. They reported that log probability plot is a close approximation to a straight line indicating a log normal distribution. Commenting on the log probability plot they reported that this type of plot is very insensitive to the shape of the distribution curve although it is useful in providing characteristics for comparative purposes and readily gives the cumulative percentage of particulates in the size range covered.

Augustine and Boubel (1975) while studying the particle size distribution of Kraft paper mill aerosol reports that the size distributions from samples close to the stack were found to have a log normal frequency distribution, but significant deviations from the log normal were found further downwind.

Lundgren and Paulus (1975) after studying the mass distribution of large atmospheric particles reported that the atmospheric particulate matter has a bimodal mass distribution. Whitby and Cantrell (1975) while reviewing some important aspects of the characteristics of atmospheric aerosols reported that a major discovery of the last six years has been essentially the bimodal nature of the aerosol size distribution.

Thus it is clear that particulate matter may be interpreted in different ways. A plot of particle size and cumulative percentage of particles by number or mass is useful in almost all type of studies.

3. PLANNING AND METHODOLOGY

3.1 PLAN FOR DETAILED STUDY:

The proposed study involves three distinct aspects:

(1) Field Investigations-Measurements and sampling of air pollutants emitted by steams locomotives, and their concentrations in ambient air of the locoyard.

(2) Laboratory Work- Physical and chemical analyses of collected field samples for quantitative determination of the desired parameters.

(3) Assessment of Emission Factor- Rate of emission of particulates and sulphur dioxide from different steam locomotives were ascertained by determining the concentrations of these pollutants and the quantity of exhaust gas from the locomotives, to arrive at the emission factors with respect to the rate of coal consumption.

3.1.1 Field Investigations:

It was proposed to collect samples for particulate matter and sulphur dioxide emitted by steam locomotives, which seem to be major pollutants in the case of steam locomotives. Ambient air quality was also monitored for sulphur dioxide, dust fall, and suspended particulate matter. One year incidence data for some respiratory

diseases were collected from loco hospital to have an idea about the health hazards in terms of respiratory diseases.

3.1.2 Laboratory Analysis:

(a) Samples of bottom ash and coal from different type of locomotives were analysed for ash content and total sulphur.

(b) Particulate emission from steam locomotives were analysed gravimetrically.

(c) Suspended particulate matter in ambient air was analysed gravimetrically. Size distribution analysis by numbers was done by microscopic examination.

3.2 SAMPLING METHOD ADOPTED:

3.2.1 Drawing Samples:

Before every sample the temperature of stack gases was measured. For sampling particulate matter a millipore sampling holder was used with Whatman 42 filter papers cut to proper size. Midget impinger was used as a suction pump. The pump was regularly checked for calibrated flow of 0.1 cubic feet per minute with the help of a flow meter. Samples were drawn only for 30 seconds. For sampling of sulphur dioxide impinger

tubes were used with the cotton wool plugs to check the particulate matter. Sulphur dioxide was absorbed in the absorbing reagent and the sample was quantitatively transferred to the ordinary tube to make the impinger tube available for next sampling. Midget impinger was used as a suction pump and sample was drawn for 30 seconds at a flow of 0.1 cubic feet per minute.

3.2.2 Exhaust Gas Velocity:

For determining gas velocity a standard pitot tube was used. The velocity can be estimated by the following equation:

$$V_a = 4005\sqrt{h_v}$$

When water is used as the manometer fluid to measure the velocity of air, h_v = head in inches of water, V_a=velocity of air in feet per minute.

The volume of gas flow was determined by multiplying the cross-sectional area of the stack with the average gas velocity.

3.3 STUDY OF AMBIENT AIR:

3.3.1 Sampling Stations:

Most of the times sampling was done near the

engines, where most of the workers were engaged in maintenance. Grab samples were taken for sulphur dioxide and suspended particulate matter keeping in view that the sample represents the air to which the workers at large are exposed. Sampling was also conducted in the middle of the locoshed and at both the ends. One full day sampling was done in the centre of the sheds so as to check the variation in concentrations with respect to time.

3.3.2 Method of Sampling and Analysis:

The suspended particulate matter collected on particulate filter paper (glass-fibre filter, M.S.A.), which have lesser affinity for moisture. The measured volume of air was sucked through filter papers with the help of midget impinger. Difference in filter paper weight gave a measure of the amount of dust present in the air sampled. High volume sampler was used at a rate of 30 cubic feet per minute, when one full day sampling was conducted.

For the determination of sulphur dioxide in the ambient air, gas samples were collected by standard impingers (Midget impingers) in suitable solvents with a sampling rate of 0.1 cubic feet per minute and analysis

made according to suitable micro-methods as reported in section 4.3.2.

3.3.3 Collection of Dust Fall:

A two litre capacity jar of 10 cm diameter was placed for a month on the roof of a building in the centre of the locoyard. One litre of distilled water with 2.5 gm of $CuSO_4$ dissolved in it was kept. pH of the solution was measured before and after the dust collection.

4. ANALYTICAL METHODS USED

4.1 METEOROLOGICAL MEASUREMENTS:

4.1.1 Temperature:

A sensitive mercury-in-glass thermometer with a range of 0-100°C and a least count of 0.5°C was used for the measurement of ambient air temperature. The thermometer was kept suspended in an open place such that the thermometer bulb comes in contact with the air surrounding it.

4.1.2 Wind Speed:

A Vane-Anemometer was used for measuring the wind speed in feet per minute.

4.1.3 Relative Humidity:

A sling psychrometer was used to measure the dry and wet bulb temperatures for the determination of relative humidity.

4,2 CHEMICAL ANALYSIS OF COAL AND DUST SAMPLES:

4.2.1 Determination of Moisture in Coal:

1 gm of coal sample (passing BSS sieve No.60) was

accurately weighed in a silica dish and dried for 1 hour in an air-oven at a temperature of 108 $\pm$ 2^{o}C. The sample was cooled in a desiccator, covered and reweighed. The loss in weight percent represents the moisture content.

4.2.2 Determination of Volatile Matter in Coal and Dust:

1 gm of coal (passing BSS sieve No.60) was accurately weighed in a silica crucible. The sample was covered with the lid and placed in a muffle furnace heated to 925^{o}C for 7 minutes and then the crucible was taken out, cooled and weighed again. The dust sample was also heated similarly. The loss in weight indicates the volatile matter and moisture.

4.2.3 Determination of Ash in Coal Sample:

The dish containing the residue from the moisture determination was placed in the furnace and the temperature was raised to 950^{o}C. The incineration was continued until no further loss in weight occured (normally 1 hour). The dish from the furnace was then removed, covered, cooled and reweighed. The residue in the dish was expressed as percentage of ash in the coal samples.

and formaldehyde produces red-purple colour which was measured at a wave length of 560 nm. Figure 1is the standard curve for sulphur dioxide determination.

4.3.3 Particle Size Measurement:

The particle size measurement of the air-borne dust samples was determined with the help of a microscope (Allen, 1968). Size was measured as a diameter of the sphere of the equivalent volume.

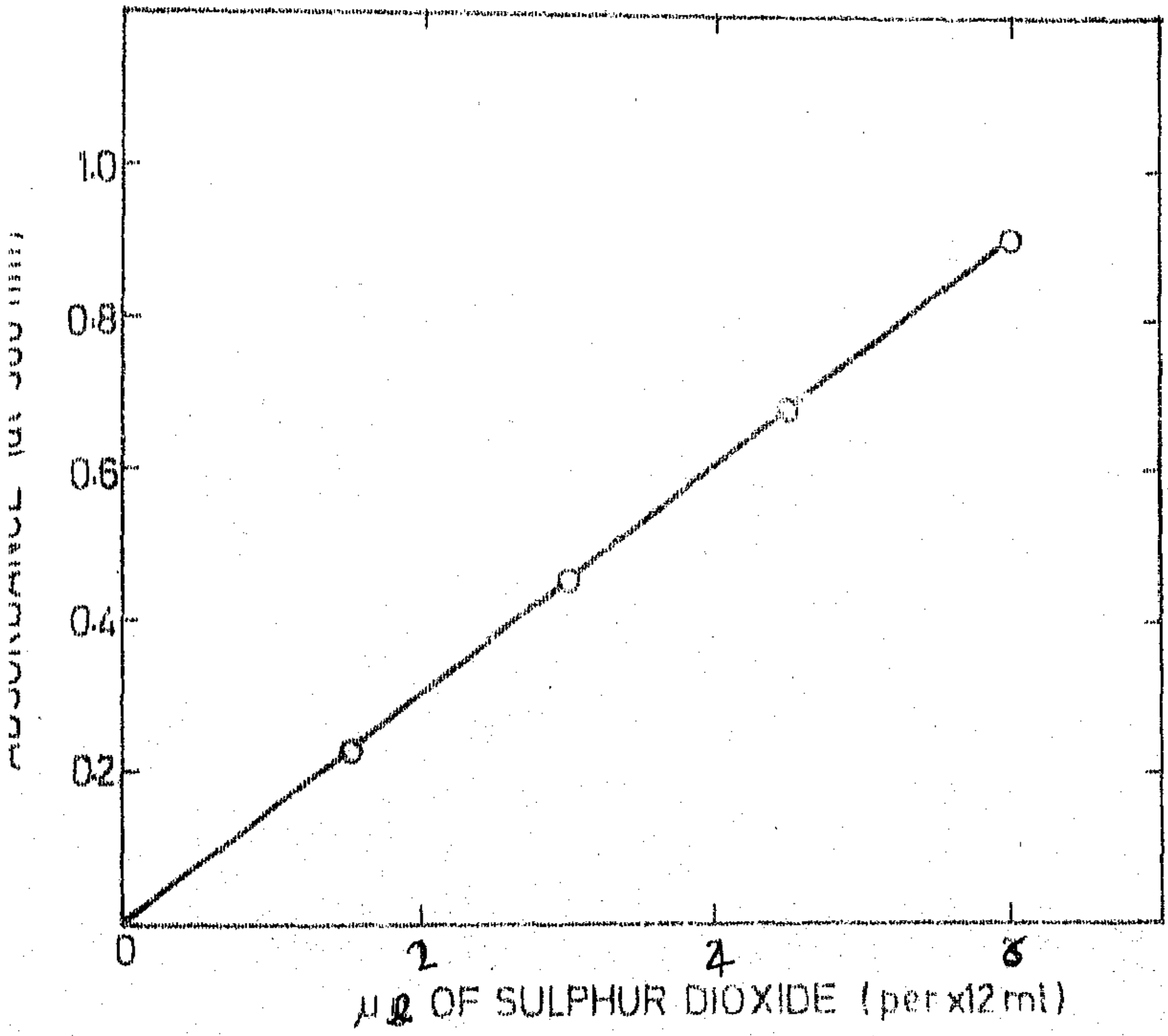

FIG.1 STANDARD CURVE FOR DETERMINING SO_2

5. RESULTS AND DISCUSSION

5.1 EMISSION FACTORS

It has been observed that concentrations of SO_2 and particulate matter (Tables 10 and 11) are slightly higher in stationary position of locomotives as compared to moving position. The reasons for this difference conceivably could include higher exhaust gas velocities, higher induced draft and more air supply in case of locomotives in moving position.

Tables 12 and 13 give the emission factor for four different types of steam locomotives in stationary and moving positions. The variations in the emission factors in stationary and moving positions may be attributed to the lower fuel consumption by the locomotive while in stationary position. Emission factors are highest for CWD type of locomotives and lowest for WG type of locomotives. Both of these locomotives are designed for hauling goods train. CWD type locomotives are imported one which are used for light load hauling while WG type are manufactured in India and are used for heavy load hauling. It seems that combusion is very good in CWD type of locomotives. This point may be

TABLE 10

AVERAGE CONCENTRATIONS OF SULPHUR DIOXIDE AND PARTICULATE MATTER IN EXHAUST GASES OF STEAM LOCOMOTIVES IN STATIONARY POSITION

Engine Type		WITH BLOWING			WITHOUT BLOWING		
		SO_2, mg/m^3	Particulate, mg/m^3	Gas flow Rate, $m^3/sec.$	SO_2, mg/m^3	Particulate mg/m^3	Gas Flow Rate, $m^3/sec.$
8740	WG	170.0	494.0	2.36	136.0	459.0	1.365
12564	CWD	380.0	494.0	2.73	376.0	494.0	1.365
1251	WP	194.0	565.0	3.35	194.0	529.5	1.920
24440	HPS_2	328.0	494.0	2.36	233.0	459.0	1.365

TABLE 11

CONCENTRATIONS OF SO_2 AND PARTICULATE MATTER IN EXHAUST GASES OF STEAM LOCOMOTIVES IN MOVING POSITION

Engine Type	SO_2, mg/m^3	Particulate, mg/m^3	Gas flow rate $m^3/sec.$
10330 WG	151.5	353.0	3.86
12451 CWD	255.0	494.0	3.86
7564 WP	193.0	424.0	4.09
24435 HPS_2	138.5	353.0	4.31

TABLE 12

EMISSION FACTORS FOR STEAM LOCOMOTIVES

IN STATIONARY POSITION

(Average Coal Consumption = 0.8 Tonne/hour)

Engine Type	Sulphur Dioxide Kg/Tonne of Coal	Particulate Matter Kg/Tonne of Coal
8740 WG	1.00	3.23
12564 CWD	2.78	3.54
1251 WP	1.90	5.24
24440 HPS_2	1.60	3.03

TABLE 13

EMISSION FACTORS FOR STEAM

LOCOMOTIVES IN MOVING POSITION

(Average Coal Consumption = 1.5 Tonne/hour)

Engine Type	Sulphur Dioxide Kg/Tonne of Coal	Particulate Matter Kg/Tonne of Coal
10330 WG	1.40	3.26
12451 CWD	2.36	4.58
7564 WP	1.89	4.15
24435 HPS_2	1.43	3.65

supported from percentage of sulphur present in bottom ash of different type of locomotives (Table 14). The sulphur content in bottom ash was lowest in CWD type locomotives among all the types of locomotives considered in this study.

5.2 AMBIENT AIR QUALITY

5.2.1 Concentration Of SO_2 And Suspended Particulate Matter :

In ambient air it was observed that concentration of SO_2 varied approximately from 0.1 to 0.3 ppm while that of particulate matter varied from 3.53 to 7.06 mgm/m^3. Product of SO_2 and particulate matter concentrations varied between 1.02 and 5.55 $(mgm/m^3)^2$.(Table 15). Thus the concentration of SO_2 was higher than the primary and secondary standards (Table 7). Particulate matter concentration was always higher than the prescribed standards (Tables 7 and 8). Product of SO_2 and particulate matter was always higher than the U.S. emergency level criteria of 0.393 $(mgm/m^3)^2$.

One full day study (Table 17) indicated the SO_2 concentrations from 0.153 to 0.309 ppm and suspended particulate matter in the range of 1.41 to 4.71 mgm/m^3. Product of SO_2 and particulate matter varied from 0.882

TABLE 14

COAL AND ASH ANALYSIS FOR DIFFERENT TYPES OF LOCOMOTIVES

Engine Type	Coal		Percent Sulphur In Bottom Ash
	Percent Ash	Percent Sulphur (Total)	
10330 WG	14.2	0.6	0.22
12451 CWD	14.2	0.6	0.17
7564 WP	14.2	0.6	0.24
24435 HPS_2	14.2	0.6	0.21

TABLE 15

SULPHUR DIOXIDE AND SUSPENDED PARTICULATE MATTER CONCENTRATIONS IN AMBIENT AIR

Date	Sampling Station	Temp. °C	R.H. %	SO_2 ppm	SO_2 mg/m^3	Particulate Matter mg/m^3	Product SO_2 and Particulate $(mg/m^3)^2$
10/6/76	Centre of Shed	37.2	54	0.118	0.307	7.06	2.17
10/6/76	Right Hand Side of Shed	40.0	44	0.149	0.391	7.06	2.77
8/7/76	Outside Shed	29.0	92	0.110	0.288	3.53	1.02*
8/7/76	Centre of Shed	30.0	87	0.216	0.566	3.53	2.00*
28/7/76	Inside Shed	34.5	64	0.305	0.786	7.06	5.55
28/7/76	Near Coal Dump	34.5	64	0.208	0.545	7.06	3.85
8/10/76	Near Coal Dump	36.0	30	0.210	0.550	7.06	3.89
13/10/76	Right Hand Side of Shed	35.0	30	0.140	0.367	7.06	2.59
28/10/76	Left Hand Side of Shed	32.0	31	0.271	0.710	7.06	5.02
28/10/76	Right Hand Side of Shed	32.0	31	0.140	0.367	7.06	2.59

Table 15 Contd....

Table 15 contd....

Date	Sampling Station	Temp. ^oC	R.H. %	SO_2 ppm	SO_2 mg/m^3	Particulate Matter mg/m^3	Product of SO_2 and Particulate $(mg/m^3)^2$
2/11/76	Left Hand Side of Shed	32.0	30	0.290	0.760	7.06	5.37
3/11/76	Right Hand Side of Shed	33.0	28	0.145	0.380	7.06	2.68
4/11/76	Centre of Shed	30.0	41	0.180	0.472	7.06	3.34

* It was raining

TABLE 16

DUST FALL ANALYSIS (DURATION OF SAMPLING OCT.13~NOV.12,1976)

Diameter of jar = 10.0 cm

Initial pH of water = 5.2

Final pH of water = 4.8

Weight of insoluble solids = 0.4008 gm.

Weight of soluble solids = Not detectable

Volactile matter in dust fall = 18.4%

Dust fall = 51.05 tonne/km^2/month

= 132 tonne/mile^2/month

TABLE 17

SO_2 AND SUSPENDED PARTICULATE MATTER CONCENTRATIONS IN THE AMBIENT AIR*

Time	SO_2 ppm	SO_2 mgm/m^3	Particulate matter mgm/m^3	Product of SO_2 & Particulate matter (mgm/m^3)^2	Temp. °C	R.H %
12.00 Noon	0.168	0.440	4.710	2.070	22	35.0
1.30 p.m.	0.239	0.626	1.410	0.882	23	31.0
3.00 p.m.	0.190	0.498	2.355	1.175	23	31.0
4.30 p.m.	0.309	0.810	1.640	1.330	23	29.5
6.00 p.m.	0.153	0.402	4.240	1.710	20	37.5
7.30 p.m.	0.208	0.545	3.530	1.920	19	44.5

* Date of sampling - December 14, 1976

to 2.07 $(mgm/m^3)^2$. When compared with Table 15 it is observed that suspended particulate matter concentrations, measured with High Volume Sampler are lower than those measured with the help of Midget impinger pump. The possible reason for this difference may be due to the different sampling spots and the small size of sample (1 cu.ft.) drawn with the help of Midget impinger pump. With Midget impinger pump most of the time sampling was conducted near locomotives, emitting pollutants, while the High Volume Sampler was used in the centre of the shed (for convenience of necessary power connection), where locomotives stand for major repairs. On the whole day sampling the concentrations of SO_2 were high at 1.30 p.m. and 4.30 p.m. which could perhaps be related to the time of firing and change of shift and other environmental conditions prevailing there.

5.2.2 Particle Size Distribution Of Particulate Matter :

Table 18 gives the cumulative percentage of suspended particles in various size ranges. Figure 2 is a log-probability plot between the particle size and the cumulative percentage by number $\leq$ the stated size. As high as 82.81 percent of particles are less than and equal to 10 micron in size, out of which 63.81 percent are less

TABLE 18

PARTICLE SIZE DISTRIBUTION IN AMBIENT AIR

Date of Sampling	Particle Diameter (D_p) in Microns				
	≤2.5	≤5.0	≤10	≤20	≤40
10/6/76	5	36	64	84	98
8/7/76	10	37	69	96	100
28/7/76	47	66	82	93	98
	60	78	92	100	-
	52	92	98	100	-
8/10/76	24	64	88	98	100
13/10/76	44	64	84	96	100
28/10/76	40	65	84	95	100
2/11/76	45	66	81	94	100
3/11/76	48	68	86	96	100
4/11/76	43	66	85	95	100
Average	38	63.8	82.81	95.18	99.77

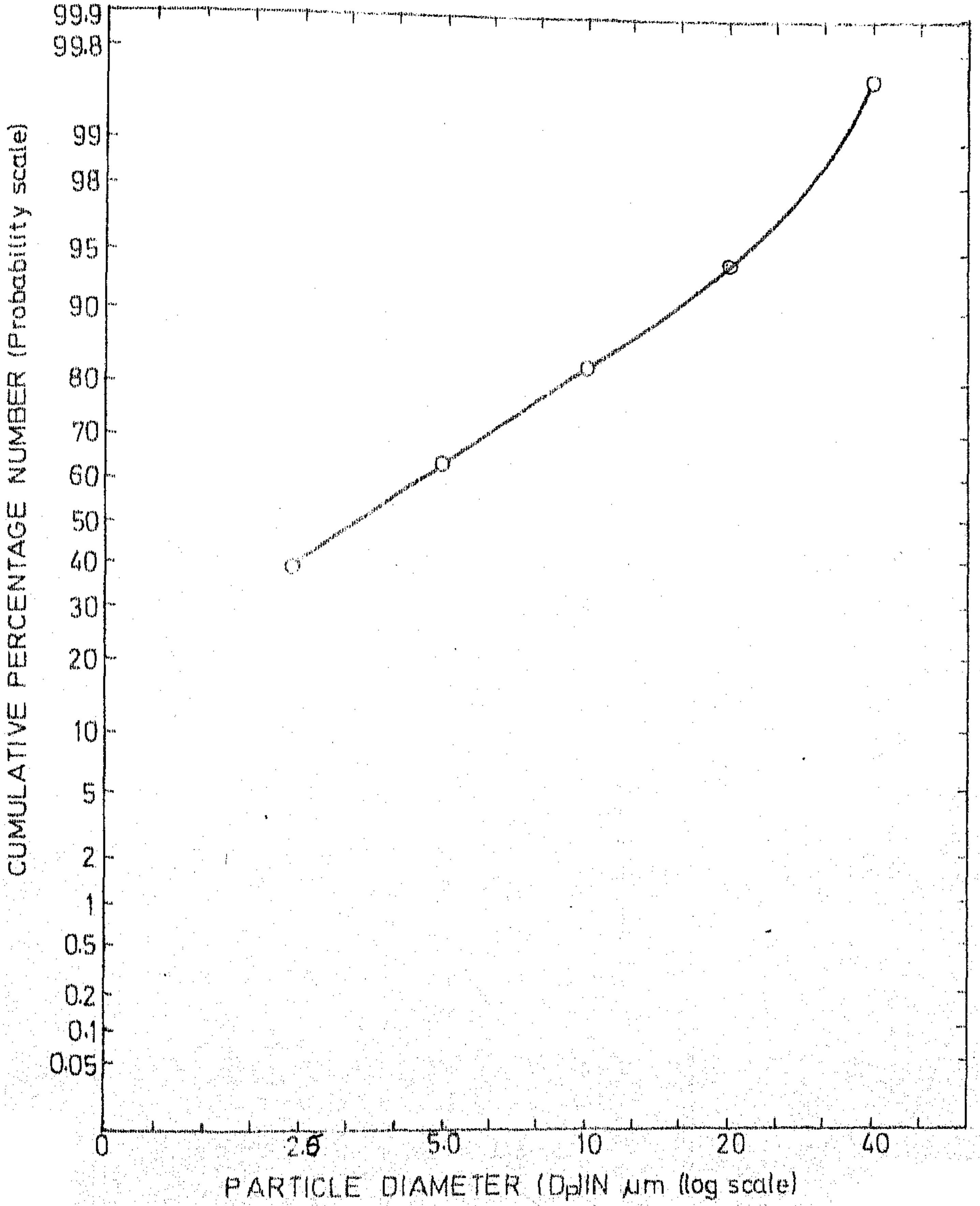

FIG.2 PARTICLE SIZE DISTRIBUTION

than and equal to 5 micron, and 38 percent are less than and equal to 2.5 microns. Such a high percentage of suspended particulate matter in size ranges affecting human health (respirable particles) may adversely affect the human health.

From Fig. 2 it is clear that upto 10 micron size the plot approximates a straight line while beyond 10 micron there is a sharp deviation from the straight line. This indicates that size distribution of particulate matter in the size ranges less than and equal to 10 micron is log normal.

5.2.3 Dust Fall :

Table 16 gives the analysis of dust fall collected over a period of one month (October 13 to November 12, 1976). Dust fall recorded was 132 tonne/sq.mile/month. This figure of dust-fall is very high when compared to those in European cities, but not so when compared to dust fall of Kanpur city which has been reported to be 20 to 280 tons/sq.mile/month (Sharma et al., 1973). After dust fall the pH of water was lowered from 5.2 to 4.8. This indicates the presence of acidic substances associated with the dust fall. 18.4% volatile matter was present in the dust fall, which

indicates the organic content.

5.3 HEALTH SURVEY:

Table 19 lists the incidence of some diseases which might be affected by air pollution. The data were collected for the period of November 1975 to October 1976. No separate data were available for the workers employed in locoyard. These data include all workers employed in locoyard and their adult family members. No attempt has been made in this study in establishing some correlation between morbidity and the level of air pollution. Following discussion, however, indicate the possible health hazard due to air pollutation in the locoyard.

Ghosh (1971) made a study of effects of air pollution on respiratory diseases. This study included the adult mades in different zones of Kanpur city. Since the present study also include the adalt males so comparison of incidence rates of respiratory diseases in two studies may point out the possibility of advrese health effects due to higher levels of air pollution. Monthly average concentrations of SO_2 varied from 0.004 ppm to 0.0875 ppm and monthly average concentration of air-borne dust varied from 71.33 microgram/m^3 to 682.30 microgram/m^3 in the study reported

TABLE 19

MONTHLY DISEASE INCIDENCE PER THOUSAND PERSON

Disease Month	T.B. of Resiratory system	Asthma and Bronchitis	Tonsilitis	Influenza	Common Cold	Diseases of Eye	Other Diseases
Nov.75	0	8.65	10.70	15.42	29.8	22.3	245.43
Dec.75	0.455	8.86	13.85	16.35	30.7	19.8	258.785
Jan.76	0.228	7.95	12.72	13.62	28.9	17.95	238.582
Feb.76	0.228	7.26	6.82	15.90	28.45	16.35	210.842
March 76	0.228	7.04	7.04	12.50	28.9	15.45	212.792
April 76	0.910	6.82	9.55	11.35	27.5	15.9	227.87
May 76	0.228	8.86	2.273	12.72	30.3	16.6	198.119
June 76	0.228	7.95	6.14	13.62	23.2	12.5	223.862
July 76	0.228	7.04	3.86	15.42	28.45	12.75	224.002
Aug. 76	0.228	6.82	8.40	15.65	25.5	8.18	206.402
Sep. 76	0.455	6.82	6.36	13.18	25.7	7.95	197.485
Oct. 76	0.455	8.40	6.14	13.40	25.0	6.83	210.106
12 Month Average	0.322	7.7	7.82	14.09	27.7	14.36	206.898

by Ghosh; while in the present study SO_2 varied from 0.1 to 0.3 ppm and particulate matter varied from 1.41 mg/m^3 to 7.06 mg/m^3.

The present study indicated lower disease incidence for asthma and bronchitis (6.82 to 8.86 instead of 6.17 to 23.71 per thousand person), whereas higher for tonsillitis (as high as 13.85 in place of 3.376). Present study indicate consistent higher incidence for common cold (25 to 30.7 instead of 5.144 to 28.352). Higher incidence rates of tonsillitis, influenza, and common cold together with high concentration of air-borne dust point that there is a possibility of causative agents of these diseases being transported on air-borne dust and in turn taken up with high percentage of respirable particulate matter.

6. CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

6.1 CONCLUSIONS

Based on the investigations given in the preceeding chapters, the following conclusions may be drawn:

(1) The different types of steam locomotives have different emission factors for sulphur dioxide and particulate matter.

(2) There is a slight variation in the emission factors in the stationary and moving positions of the steam locomotives.

(3) Among the different types of locomotives considered in this study emission factor for sulphur dioxide is lowest for WG type while it is highest for CWD type.

(4) Suspended particulate matter concentrations in ambient air are entremely high. Concentrations of sulphur dioxide are high as compared to ambient air quality standards (Table 7) but they are lower than the workroom threshold limit values (Table 8).

(5) More than eighty percent of the suspended particulate matter lies within the size range and the size distribution approximates log normal. Particles larger than 10 micron showed sharp deviation from log normal distribution.

(6) Ambient air quality of the locoyard is poor and is likely to cause adverse health effects.

6.2 SUGGESTIONS FOR FUTURE WORK

Based on the investigations of this study, it is felt that further work should be pursued in the following areas:

An exhaustive study is required for the proper assessment of emission factors for different pollutants being emitted by different types of locomotives (both steam and diesel) under different working conditions. This will be useful for a good assessment of the total contribution of air pollution by locomotives.

Chemical identification of particulate matter may be necessary as well as size distribution characterization in order to assess the potential hazard created by the presence of the particulate matter. Particle size distribution, however, is the first characteristic which must be identified and considered to assess the possible health hazard due to the presence of particulate matter in the atmosphere.

REFERENCES

Allen, T. (1968) Particle Size Measurement. Chapman and Hall Ltd., London.

Arceivala, S.J., Sabnis, C.V., and Yennawar, P.K. (editors) How to Conduct Air Pollution Surveys. National Env.Engg. Research Institute, Nagpur(3).

Augustine, F.E. and Boubel, R.W. (1975) Particle Size Distributions of Kraft Paper Mill Aerosols Obtained by Airborne Sampling. J. Air Poll. Control Assoc., 25(6), 617.

Ballaney, P.L. (1973) Heat Engines. Khanna Publishers, Delhi.

Cooper, H.B.H., Jr., Richards, H.A., and Lam, A.T.B. (1976) Air Pollution Impact of Railroad Electrification. J. Env. Engg. Div., Proc. Am. Soc. Civil Engrs., 102, 723.

Dautrebande, L., et al. (1958) New Studies on Aerosols. Arch. Intern. Pharmacodynamie, 116, 187.

Derham, R.L., Peterson, G., Sabersky, R.H., and Shair, F.H. (1974) On the Relation Between the Indoor and the Outdoor Concentrations of Nitrogen Oxides. J. Air Poll.Control Assoc., 24(2), 158.

Faith, W.L. (1959) Air Pollution Control. John Willey & Sons, Inc., New York.

Garud, M.K. (1971) Effect of Low-Level Air Pollution in Kanpur on the Growth of Children. M. Tech. Thesis submitted to I.I.T., Kanpur.

Ghosh, D.K. (1971) Air Pollution in Kanpur and Its Effects on Respiratory Diseases. M.Tech. Thesis submitted to I.I.T., Kanpur.

Gilmore, T.M. and Hanna, T.R. (1975) Applicability of the Mass Concentration Standards for Particulate Matter in Alskan Areas. J. Air Poll. Control Assoc., 25(5), 534.

Goldstein, I.F. and Block, G. (1974) Asthma and Air Pollution in two Inner City Areas in New York City. J. Air Poll. Control Assoc., 24(7), 665.

Himus, G.W. (1954) Fuel Testing. Leonard Hill Ltd., 9 Eden Street, N.W. 1.

Indian Standard Methods for Measurement of Air Pollution-Sulphur dioxide (1969). IS: 5182 (Part II).

Labelle, C.W., et al. (1955) Synergistic Effects of Aerosols-Particulates as Carried of Toxic Vapours. A.M.A. Arch. Indust. Health, 11, 297.

Ledbetter, J.O. (1972) Air Pollution-Part A. Marcel Dekker, Inc., New York.

Lee, R.E., Jr. (1972) The Size of Suspended Particulate Matter in Air. Science, 178, 567.

Lee, R.E.,Jr. (1974) The Size of Suspended Particulate Matter in Air. Science, 183, 1099.

Lundgren, D.A. and Paulus, H.J. (1975) Mass Distribution of Large Atmospheric Particles. J. Air Poll. Control Assoc., 25(12), 1227.

Mainwaring, S.J. and Harsha, S. (1976) Size Distribution of Aerosols in Melbourne City Air. Atmospheric Environment, 10(1), 57.

Manos, N.E. and Fisher, G.F. (1959) An Index of Air Pollution and its Relation to Health. J. Air Poll. Control Assoc., 9(1), 5.

Nader, J.S. (1975) Current Technology for Continuous Monitoring of Particulate Emissions. J. Air Poll. Control Assoc., 25(8), 814.

Nelson, C.J., et al.(1973) Family Shrveys of Irritation Symptoms during Acute Air Pollution Exposures: 1970 Summer and 1971 Spring Studies. J. Air Poll. Control. Assoc., 23(2), 81.

Perkins, H.C. (1974) Air Pollution. McGraw-Hill Book Company.

Prindle, R.A. (1959) Some Considerations in the Interpretation of Air Pollution Health Effects Data. J. Air Poll. Control Assoc., 9(1), 12.

Rangwala, S.C. (1971) Principles of Railway Engineering. Charotar Book Stall, Anand, India.

Ross, R.D. (editor), (1972) Air Pollution and Industry. Van Nostrand Reinhold Company.

Samson, P.J., Neighmond, G., and Yencha, A.J. (1975) The Transport of Suspended Particulates as a Function of Wind Direction and Atmospheric Conditions. J. Air Poll. Control Assoc., 25(12), 1232.

Schimmel, H. and Greenburg, L.(1972) A Study of the Relation of Pollution to Mortality. J. Air Poll. Control Assoc., 22(8), 607.

Sharma, V.P., Arora, H.C., Chattopadhaya, S.N., and Routh,T. (1973) A Limited of Air Quality at Kanpur. Indian J. Env. Health, 15(2), 133.

Stern, A.C. (1968) Air Pollution Vol I. Academic Press, New York and London.

Stern, A.C., Wohlers, H.C., Boubel, R.W., and Lowry, W.P. (editors),(1973) Fundamentals of Air Pollution. Academic Press, New York and London.

Symposium on Fuel Policy for Power Generating Stations(1972). Control Board of Irrigation and Power, 45th Annual Board Session, New Delhi.

Thompson, C.R., Hensel, E.G., and Kats, G. (1973) Outdoor Indoor Levels of Six Air Pollutants. J. Air Poll.Control Assoc., 23(10), 881.

Whitby, K.T., Husar, R.B., and Liu , B.Y.H. (1972) The Aerosol Size Distribution of Los Angeles Smog. J.Colloid and Interface Science, 39(1).

Whitby, K.T., Charlson, R.E., Wilson, W.E., and Stevens, R.K. (1974) The Size of Suspended Particulate Matter in Air. <u>Science</u>, 183, 1098.

Whitby, K.T. and Cantrell, B.(1975) Atmospheric Aerosols-Characteristics and Measurement. <u>Reprint from the International Conference on Environmental Sensing and Assessment</u>, U.S.A. 75 CH 1004-1 ICESA.

Willeke, K. and Whitby, K.T. (1975) Atmospheric Aerosols Size Distribution Interpretation. <u>J. Air Poll. Control Assoc.</u>, 25(5), 529.

Zutshi, P.K. (1970) The Air: Making it Unfit to Breathe. <u>Science Today</u>, October.